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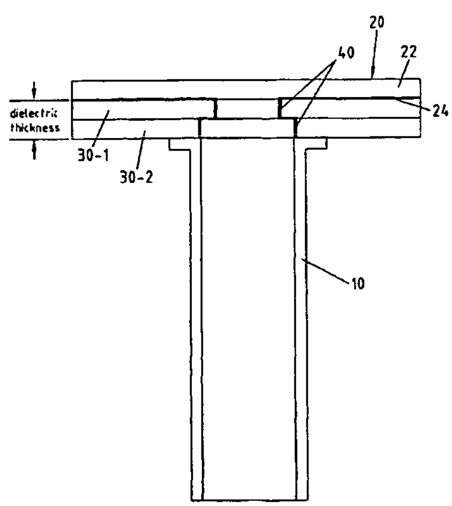
(54) Title: WAVEGUIDE TO STRIPLINE TRANSITION



(57) **Abstract:** The invention relates to a device for guiding electromagnetic waves from a wave guide (10), in particular a multi-band wave guide, to a transmission line (20), in particular a microstrip line, arranged at one end of the wave guide (10), comprising coupling means (30-1, ..., 30-7) for mechanical fixation and impedance matching between the wave guide (10) and the transmission line (20). It is the object of the invention to improve such a structure in the way that manufacturing is made easier and less expensive than according to prior art. According to the present invention that object is solved in the way that the coupling means comprises at least one dielectric layer (30) being mechanically connected with the main plane of the transmission line, the geometric dimension of that at least one dielectric layer extending along the propagation direction of the electromagnetic waves being correlated with the center frequency of electromagnetic waves in order to achieve optimised impedance matching.

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WAVEGUIDE TO STRIPLINE TRANSITION

The invention relates to a device for guiding electromagnetic waves from a wave guide, in particular a multi-band wave guide, to a transmission line, in particular a microstrip line, arranged at one end of the wave guide, comprising coupling means for mechanical fixation and impedance matching between the wave guide and the transmission line.

One problem for devices of that kind is to ensure a good transmission of electrical power in the wave guide to transmission line transition. Poor transition results in large insertion loss and this may degrade the performance of the whole module, e.g. a transceiver module.

A device with a structure known in the prior art is shown in Fig. 9. There is shown a wave guide 10 and a transmission line 20, in particular a micro strip structure which are attached to each other for enabling transition of electromagnetic waves from said wave guide 10 to said transmission line 20. Said transmission line 20 comprises a substrate 22 which is attached to a ground plane 24 for achieving good transition characteristics. The substrate 22 of the transmission line is typically made from low or high temperature co-fired ceramic LTCC or HTCC.

Impedance matching between said wave guide 10 and said transition line 20 is completed by providing a patch 26 in the transition area between said wave guide 10 and said transition line 20. Moreover, for improving impedance matching there is provided a separate slab 12 from dielectric material fastened within said wave guide 10. Said slab 12 is for example attached within said wave guide 10 between machined shoulders 14.

Said prior art approach for achieving impedance matching is based on a complex structure which can only be realised in a difficult and expensive manufacturing process. Moreover, quite often so-called back-shorts are used i.e. a metal part is attached behind the micro strip 20 opposite the opening of the wave guide 10 in order to achieve impedance matching. Attaching said back-short further increases the complexity of the structure.

It is the object of the present invention to improve the known device for guiding electromagnetic waves in a way that the manufacturing process is made easier and less expensive.

Said object is solved by the subject matter of claim 1.

More specifically, said object is solved for the structure described above in the way that the coupling means comprises at least one dielectric layer being mechanically connected with the main plane of the transmission line, the geometric dimension of that at least one dielectric layer which extends along the propagation direction of the electromagnetic waves being correlated with the center frequency of the electromagnetic waves.

Because the mechanical fixation function and the electrical impedance matching function are integrated into one single component the manufacturing process of said layer structure is easy and inexpensive.

Impedance matching is achieved according to the present invention by varying the thickness of the at least one dielectric layer between the wave guide and the transmission line. The layer structure can, even if it comprises several layers, be considered as only one element used for achieving impedance matching. Thus, the adjustment process for achieving impedance matching is facilitated.

Preferred embodiments of the invention are described in the subclaims.

A preferred example is that the transmission line is an integral part of the coupling means. In that case the entire transition structure is co-fired in a multilayer ceramics manufacturing process.

A further preferred feature to enable optimised impedance matching is to provide metallised vias within a layer in order to build up a fence-like structure to further guide the waves after the have left the end of the wave guide.

Further preferably, there is at least one additional layer provided between the transmission line or said at least one layer and the wave guide said additional layer comprising an air-filled cavity. Said additional layer strengthenes the mechanical stability of the structure and said air-filled cavity ensures that said additional

layer does not influence the transition characteristics of said structure.

It is advantageous that said cavity is aligned with an opening of the wave guide because in that case the undesired influence of said additional layer to the transition characteristics of the structure is reduced to a minimum.

Furthermore, it is advantageous that the attachment of the wave guide to the layer adjacent to the wave guide is a solder ball connection because in that case self-aligning characteristics of said solder ball connections can be used.

The invention is described in detail in the following accompanying figures, which are referring to preferred embodiments, wherein:

Fig. 1 discloses a first embodiment of a structure according to the present invention;

Fig. 2 is a diagram illustrating the transition characteristics of a wave guide to microstrip transition according to the present invention;

Fig. 3 is a diagram illustrating the relationship between the centre frequency and the dielectric thickness for optimal impedance matching in a structure according to the present invention;

Fig. 4 is a diagram illustrating the transition characteristics of a wave guide to micro strip transition or to a structure according to the

present invention wherein the thickness of the layers in the structure is varied;

Fig. 5 shows a second embodiment of the structure according to the present invention;

Fig. 6 illustrates a manufacturing process for layers comprising vias;

Fig. 7 shows a third embodiment of a structure according to the present invention;

Fig. 8 is a top view of the structure shown in Fig. 7; and

Fig. 9 shows a structure for guiding waves known from the prior art.

Fig. 1 shows a structure for guiding electromagnetic waves according to a first embodiment of the invention. The structure comprises a wave guide 10 and a transmission line 20, the substrate layer 22 of which is arranged perpendicular to the longitudinal axis of the wave guide 10 for transition of electromagnetic waves from said wave guide 10 to said transmission line 20. There are two layers 30-1 and 30-2 provided as coupling means, the layers 30-1, 30-2 being arranged between the substrate layer 22 of said transmission line 20 and said wave guide 10, wherein the dielectric thickness of said layers 30-1, 30-2 is adjusted in a way described in the following.

Each of the layers 30-1, 30-2 comprises metallised through-holes 40, called "vias", forming a fence-like

structure surrounding the area of each layer 301, 30-2, respectively, through which the wave should be guided. Vias of different layers are interconnected with each other and with a metallised layer 24 at the bottom side of the substrate layer 22 of the transmission line 20. In the following the influence of a variation of the thickness of the layers 30-1 and 30-2 on the transition characteristics of the structure according to Fig. 1 will be illustrated in more detail by referring to Figs. 2 to 4.

Fig. 2 illustrates the electrical characteristic of the structure according to Fig. 1. Fig. 2 shows the frequency curves of the transmission coefficient (S_{12}), the reflection coefficient (S_{11}) measured from port 1 and the reflection coefficient (S_{22}) measured from port 2, respectively. More specifically, it can be seen that at a centre frequency of 58 GHz and a thickness of the dielectric layer of 250 microns the characteristics are quite good. The curve S_{11}, representing the return loss of said structure for different frequencies, shows that the return loss at the centre frequency of 58 GHz is smaller than 13,5 dB, while the insertion loss, represented by the curve S_{12}, is 0,8 dB.

Moreover, the -1,5 dB bandwidth reaches from 55 ... 64 GHz, meaning that the transition is not sensitive to tolerances or manufacturing process fluctuations.

Fig. 3 illustrates that the centre frequency of the pass-band of said structure according to Fig. 1 has a linear dependency of the dielectric substrate thickness. That dependency, which is the result of a finite-element method simulation, means that just by selecting a

suitable dielectric thickness one can easily adjust the centre frequency of the transition.

Fig. 4 illustrates the insertion losses for a wave guide to micro strip transition of a structure according to Fig. 1 for different thicknesses of the dielectric layers. The insertion loss represented by the parameter S_{12} is illustrated in Fig. 4 for a dielectric thickness of 200 and 500 microns. The centre frequency of the -1,5 dB bandwidth lies in the case of a dielectric thickness of 200 microns at 63 GHz whereas for a layer thickness of 500 microns the centre frequency lies at 45 GHz. In both cases the bandwidth is approximately 7,5 GHz.

As illustrated above besides varying the thickness of the layers impedance matching can further be influenced and be improved by placing via-fences in the dielectric layer(s) and/or the substrate to define lateral dimensions of the continuation of the wave guide and thus, effect inter alia the insertion loss.

Fig. 5 shows a second embodiment of a structure according to the present invention in which three layers, 30-1, 30-2, 30-3, between the substrate 22 of the transmission line 20 and the wave guide 10 comprises vias 40. Quite often it is sufficient to optimise just only the dimensions of the layer 30-1 directly beneath the micro strip ground plane 24 and to keep elsewhere in the substrate the dimensions equal to the cross-sectional area of the metal wave guide 10. In general it appears that the larger the dimensions of the wave guide continuation structure in the dielectrical substrate of the layers 30-1, 30-2, 30-3 and the transmission line 20, the smaller the insertion loss.

According to the present invention the preferred material for the dielectrical layers is low or high temperature co-fired ceramic LTCC or HTCC.

The process for manufacturing said layers comprising vias is illustrated in Fig. 6. In a first step S1, the substrate is generated by mixing solvents, ceramic powder and plastic binder and generating substrate tapes. After drying and stripping (method step S2) and cutting out to size (method step S3) vias are punched into said substrate (method step S4.) Normally the diameter of the vias is about 100 to 200 µm. After punching of the vias, the vias of each individual layer are filled by a conductor paste like silver, copper or tungsten, see method step printing into vias S5. After that, several layers are collected and are fired together as known from a normal manufacturing step of co-fired ceramic technology. These final method steps are illustrated in more detail in Fig. 6 wherein after method step S5 conducting pads with a given surface pattern are screened on the layer according to method step 6, several layers are laminated together in method step S7 and after that, the layer assembly is fired according to method step S8. Finally braze pins are attached to the fired layer assembly according to method step S9.

Fig. 7 shows a third embodiment for a structure for guiding electromagnetic waves according to the present invention. It substantially corresponds to the structure shown in Fig. 5 however, the implementation of the vias in the layers is shown in more detail and layers 30-4 ... 30-7 are additionally comprised within the structure.

Whereas in Fig. 5 all layers 30-1, ... 30-3 have the same thickness, the thickness of layer 30-2 in Fig. 7 has been varied in order to achieve good impedance matching. E.g., for achieving good impedance matching at a particular frequency of 60 GHz it has been found that the appropriate thickness of layers 30-1 and 30-4 to 30-7 shall be 100 µm, whereas the thickness of layer 30-2 is proposed to be 150 µm.

The vias in the dielectric substrate layers do not only influence the impedance matching but also have an important roll in the mechanical design of the structure because they preferably connect the ground planes 24, 31, 32 of the transmission line 20 and of different layers 30-1, 30-2. In that way the vias ensure mechanical stability of the structure. However, if there are only very few layers provided between the transmission line 20 and the wave guide 10 the resulting structure may still be mechanically fragile. To prevent this, additional layers 30-4, ... 30-7 may be added to the substrate. These additional layers preferably build up an air-filled cavity 50 aligned to the opening of the wave guide 10 in order not to change the desired electric characteristics of the structure by changing the dielectric thickness and consequently the resulting centre frequency. The structure can further be strengthened by using a metal base plate 37 having a slot 4 aligned with the opening of the wave guide 10.

The ground plane 24 of the transmission line 20 as well as the ground planes 31, 32 and 37 of layers 30-1, 30-2 and 30-7 have slots slot 1, ... slot 4 in order to ensure a proper transition of electromagnetic waves from the wave guide 10 to the transmission line 20. These slots

may be delimited by the via fences 41, 42 of the respective layers 30-1, 30-2. However, the air-filled cavity 50 and the co-ordinated slot 4 in base plane 37 of layer 30-7 can be limited either by the dielectric substrate material itself or by the substrate material and vias 44 - 47 placed on each side of the cavity 50. While quite often the design rules prevent to place the vias close to the cavity 50 a better solution is to place the vias 50 half-wavelength away from the cavity edge; e.g. in Fig. 7 the vias 44, ... 47 are placed at a distance of 860 µm away from the cavity edge. Half-wavelength distance of the vias from the wave guide opening or the cavity edge in that part of the structure which is close to the wave guide 10 is preferably selected because at that distance the reflection coefficient ρ is $\rho = -1$, which means that such an arrangement gives almost equal performance to the case that the cavity walls have been totally metallised (half-wavelength demand comes from the fact that standing waves have a half-wavelength periodicy meaning that in effect the cavity walls seem to be in zero potential). The proposed half-wavelength arrangement also prevents any electromagnetic leakage into/from the structure.

The vias obviously improve the transition of electromagnetic waves from a wave guide 10 to a transition line 20 but they are not mandatory in every layer.

Fig. 8 shows a top view of the structure according to Fig. 7 wherein arrow 60 indicates the view direction of Fig. 7. Reference numeral 20 indicates the transmission line, in particular a micro strip structure having a width g of g = 110 µm. Said transmission line 20 has a

dielectrical thickness of 100 μ (see Fig. 7) and extends c = 130 μm over slot 1 in the micro strip ground plane 24. The area covered by said slot 1 in the ground plane 24 measures in the example according to Fig. 8 e x d wherein e = 1840 μ and d = 920 μm.

Slots 2 and 3 are represented by the thick dashed line in Fig. 8 covering an area of h x a wherein h = 1200 μ and a = 3760 μm. Said thick dashed line also represents the via fences 41 and 42 since these via fences should be placed as close as possible to the edge of the respective ground planes 31 and 32 (see Fig 7).

Fig. 8 further shows a top view on vias 44 of layer 30-4 (see Fig. 7). It is apparent that these via fences 44 and the via fences 45, 46, 47 of the beneath layers 30-5, 30-6 and 30-7 are positioned at a distance f, wherein f = 860 μm from the edge of slot 3 which substantially corresponds to the edge of air cavity 15; the reasons for placing vias 44 - 47 at a distance to the edge of the air cavity 50 have been explained above.

Slot 4 represents the cross-sectional area a x b of the air cavity in layers 30-4, ... 30-7 according to Fig. 7. In the example of Fig. 8 a = 3760 μ and b = 1880 μ, wherein that area corresponds to the cross-sectional area of the opening of wave guide 10 and is aligned thereto.

The wave guide 10 can be attached to the adjacent layer 30-7 by using different mechanical approaches: e.g. by soldering or even using solder balls, e.g. BGA (Ball Grid Array) type of solder attachment. Using a solder ball connection has the advantage that self-aligning effects of said technology can be used. On the other hand when

using solder ball connections there may be small air gaps between the connection between the wave guide 10 and the adjacent layer, however these very small air gaps do not substantially influence the electrical characteristics of the structure; thus, no direct contact between the wave guide 10 and the ceramic material of the layer is required.

Although the invention has been described for the usage of multilayer ceramics the substrate material of the transmission line 20 and of the layers 30-i may also be laminate material. The transmission line may be a micro strip, a stripline or a coplanar wave guide.

CLAIMS

1. Device for guiding electromagnetic waves from a wave guide (10), in particular a multi-band wave guide, to a transmission line (20), in particular a microstrip line, arranged at one end of the wave guide (10), comprising coupling means (30-1, ... 30-7) for mechanical fixation and impedance matching between the wave guide (10) and the transmission line (20),
characterised in that the coupling means comprises at least one dielectric layer (30) being mechanically connected with the main plane of the transmission line, the geometric dimension of that at least one dielectric layer extending along the propagation direction of the electromagnetic waves being correlated with the center frequency of electromagnetic waves in order to achieve optimised impedance matching.

2. Device according to claim 1,
characterised in that the coupling means comprise a plurality of dielectric layers arranged in a sandwich structure each of which layers having a predetermined thickness in a way that the total dielectric thickness is adapted to the center frequency of the electromagnetic waves.

3. Device according to claim 2,
characterised in that the structure comprising at least one dielectric layer is fixed, e.g. soldered or welded, to a substrate layer (22) of the transmission line (20).

4. Device according to claim 1, **characterised in that** the transmission line (20) is an integral part of the coupling means (30-1, ..., 30-7).

5. Device according to claim 1, **characterised in that** the at least one dielectric layer (30) comprises an opening extending along the propagation direction of the electromagnetic wave.

6. Device according to claim 5, **characterised in that** the opening is formed as an electrically conducting via.

7. Device according to claim 6, **characterised in that** the vias are formed as variety of staggered vias in different dielectric layers (30).

8. Device according to claim 6, **characterised in that** the vias of different dielectric layers (30) are adjacent to each other.

9. Device according to claim 6, **characterised in that** in a single layer a plurality of vias is comprised, the vias forming a fence-like arrangement which defines the lateral dimensions of the part of the layer effective for the transition of the waves.

10. Device according to claim 6, **characterised in that** the via is electrically connected with conducting pads according to given surface patterns, the pads extending along at least one main area of the layer.

11. Device according to claim 10, **characterised in that** conducting pads of adjacent layers in a sandwich structure device are electrically connected to each other.

12. Device according to claim 5, **characterised in that** the opening is a slot, in particular a rectangular recess.

13. Device according to claim 2, **characterised in that** a metal layer is arranged in the sandwich structure adjacent to the substrate layer (22) of the transmission line.

14. Device according to claim 2, **characterised in that** at least one additional layer (30-4 to 30-7) is provided within the coupling means, said additional layer confining an air filled cavity (50).

15. Device according to claim 14, **characterised in that** the cavity (50) is aligned with an opening of the wave guide (10).

16. Device according to claim 1, **characterised in that** the attachment of the wave guide (10) to the dielectric layer adjacent to the wave guide (10) is made by a soldering or welding or glueing connection.

17. Device according to claim 16, **characterised in that** the soldering connection is using solder balls.

18. Device according to claim 1, **characterised in that** the lateral dimension of the fence like via structure is located in half wave length distance from the cavity.

19. Device according to claim 1, **characterised in that** the transmission line is a microstrip line.

20. Device according to claim 1, **characterised in that** the transmission line is a stripline.

21. Device according to claim 1, **characterised in that** the transmission line is a coplanar wave guide.

22. Transition between a wave guide (10) and a transmission line (20) comprising coupling means (30-1, ... 30-7) for mechanical fixation and impedance matching between the wave guide (10) and the transmission line (20), **characterised in that** the coupling means comprises at least one dielectric layer (30) being mechanically connected with the main plane of the transmission line, the geometric dimension of that at least one dielectric layer extending along the propagation direction of the electromagnetic waves being correlated with the center frequency of electromagnetic waves in order to achieve optimised impedance matching.

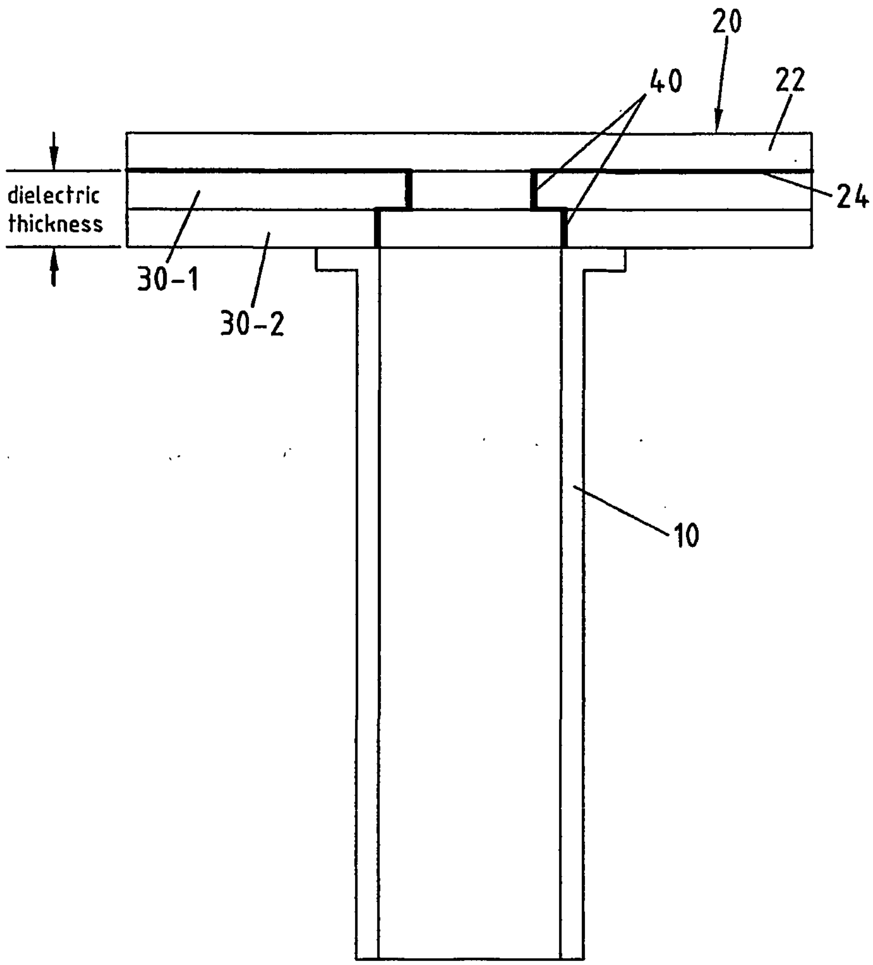
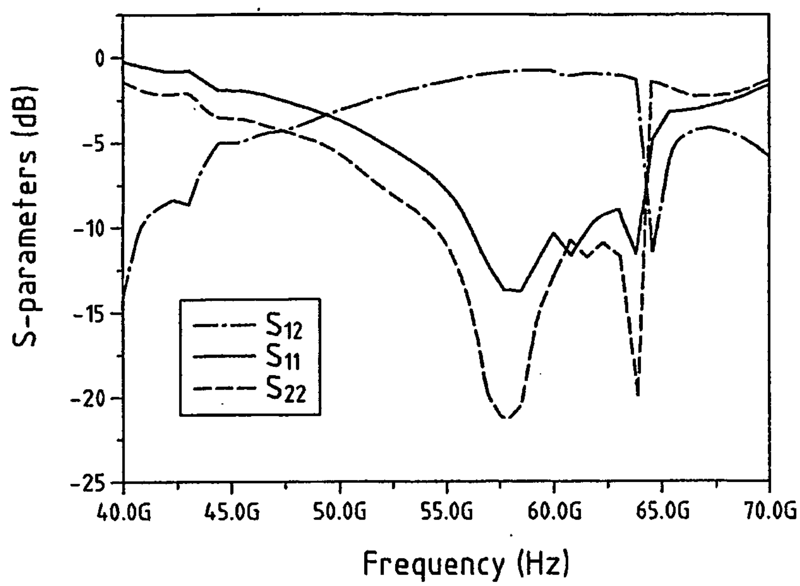


Fig.1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-5
-10
-15
-20
-25
S12
S11
S22
40.0G
45.0G
50.0G
55.0G
60.0G
65.0G
70.0G
Frequency (Hz)

Fig.2

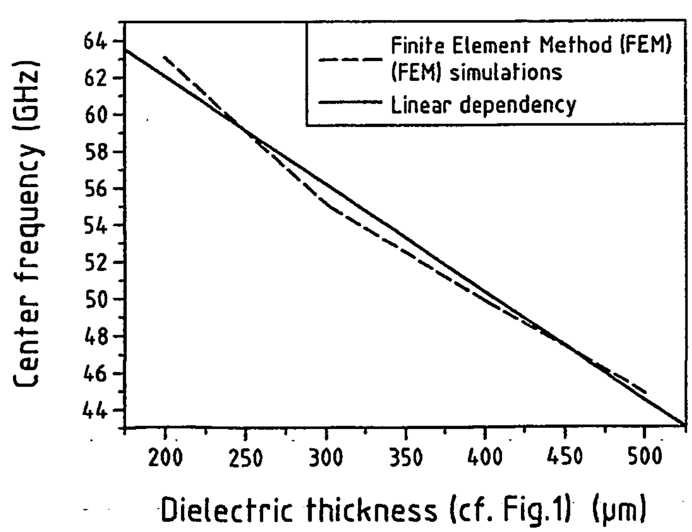
Center frequency (GHz)
64
62
60
58
56
54
52
50
48
46
44
Finite Element Method (FEM)
(FEM) simulations
Linear dependency
200
250
300
350
400
450
500
Dielectric thickness (cf. Fig.1) (µm)

Fig.3

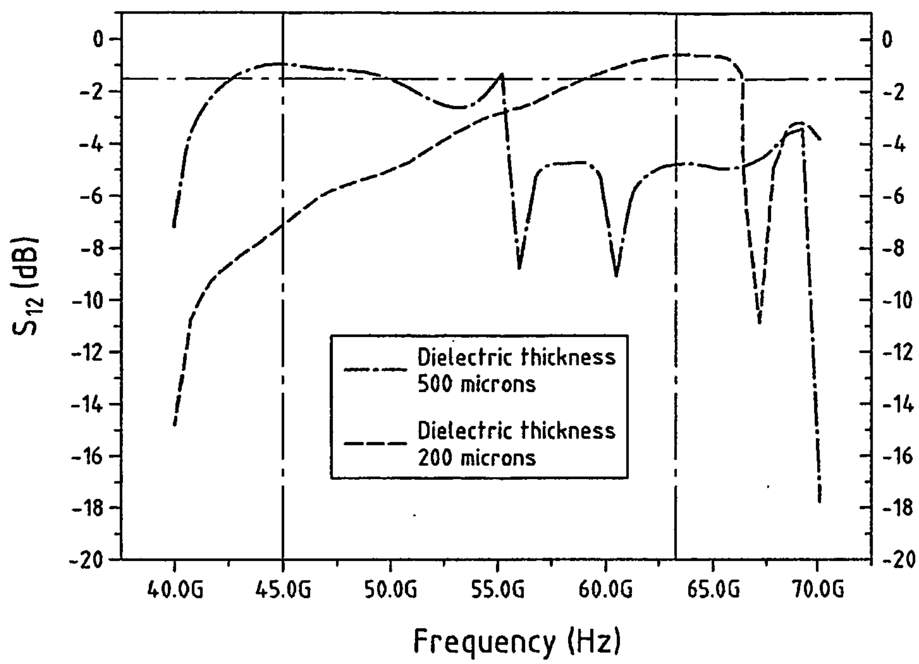
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
S_{12} (dB)
40.0G
45.0G
50.0G
55.0G
60.0G
65.0G
70.0G
Frequency (Hz)
Dielectric thickness 500 microns
Dielectric thickness 200 microns

Fig.4

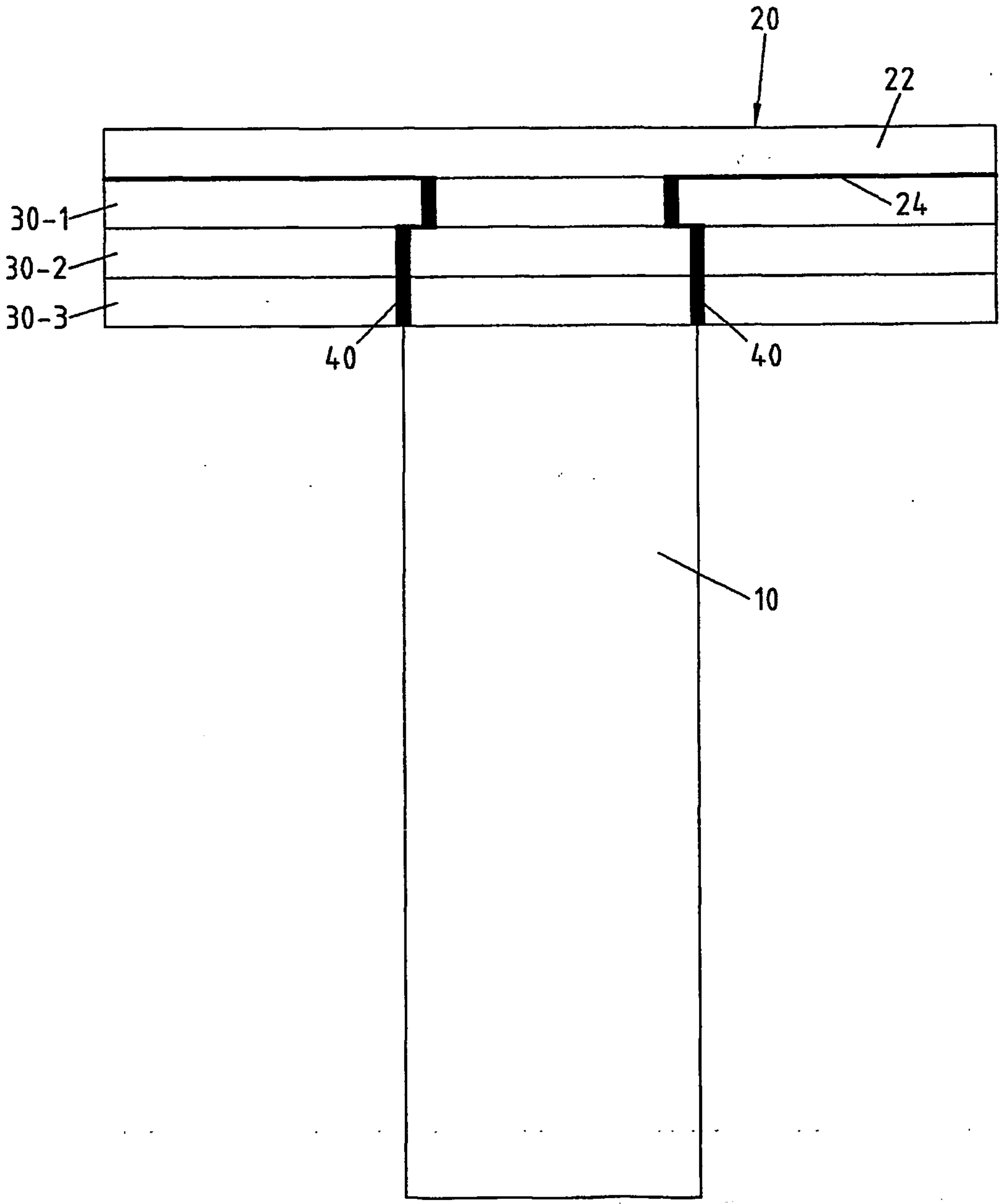

Fig.5

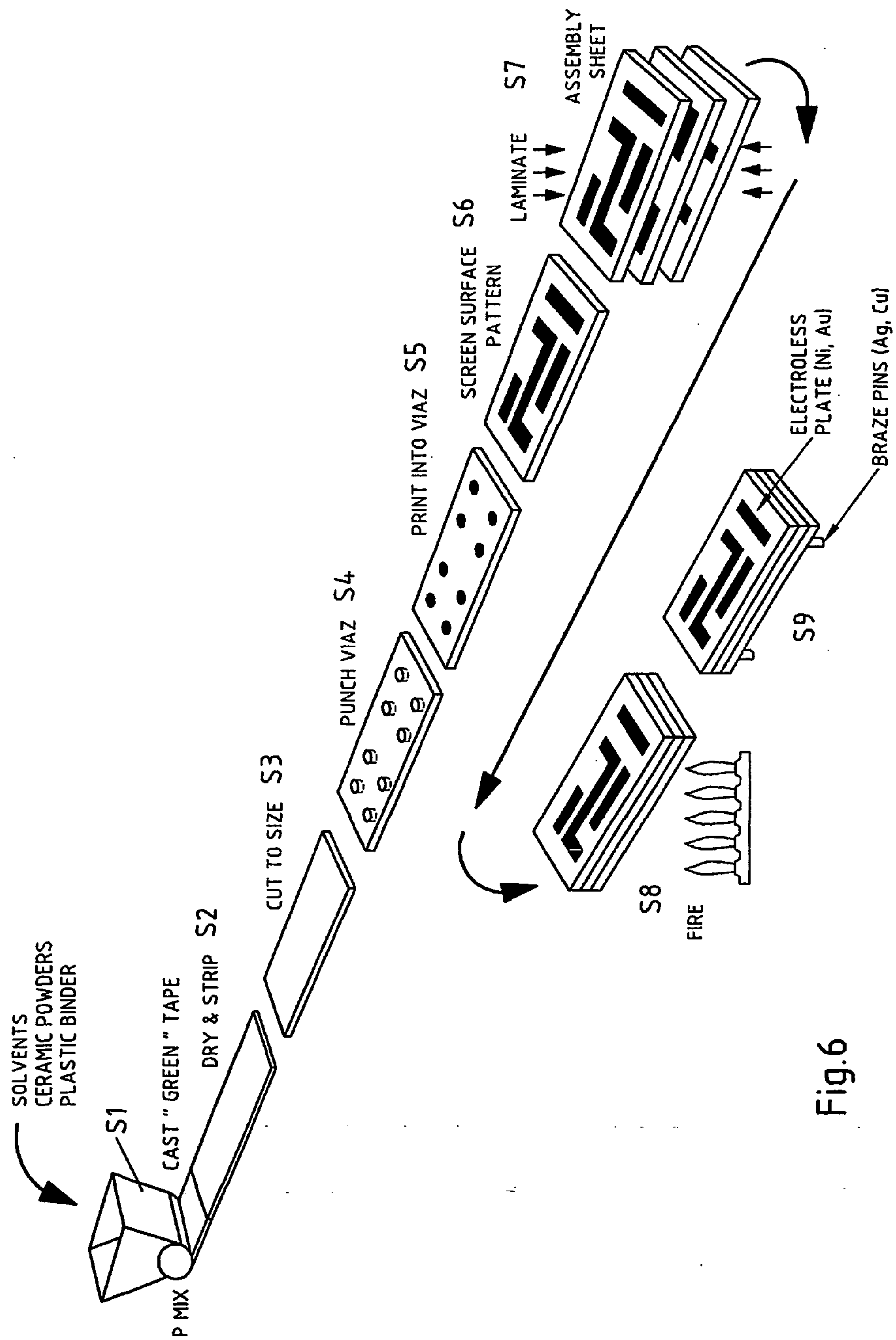
SOLVENTS
CERAMIC POWDERS
PLASTIC BINDER
S1
P MIX
CAST " GREEN " TAPE
DRY & STRIP
S2
CUT TO SIZE
S3
PUNCH VIAZ
S4
PRINT INTO VIAZ
S5
SCREEN SURFACE
PATTERN
S6
LAMINATE
S7
ASSEMBLY
SHEET
S8
FIRE
ELECTROLESS
PLATE (Ni, Au)
BRAZE PINS (Ag, Cu)
S9

Fig.6

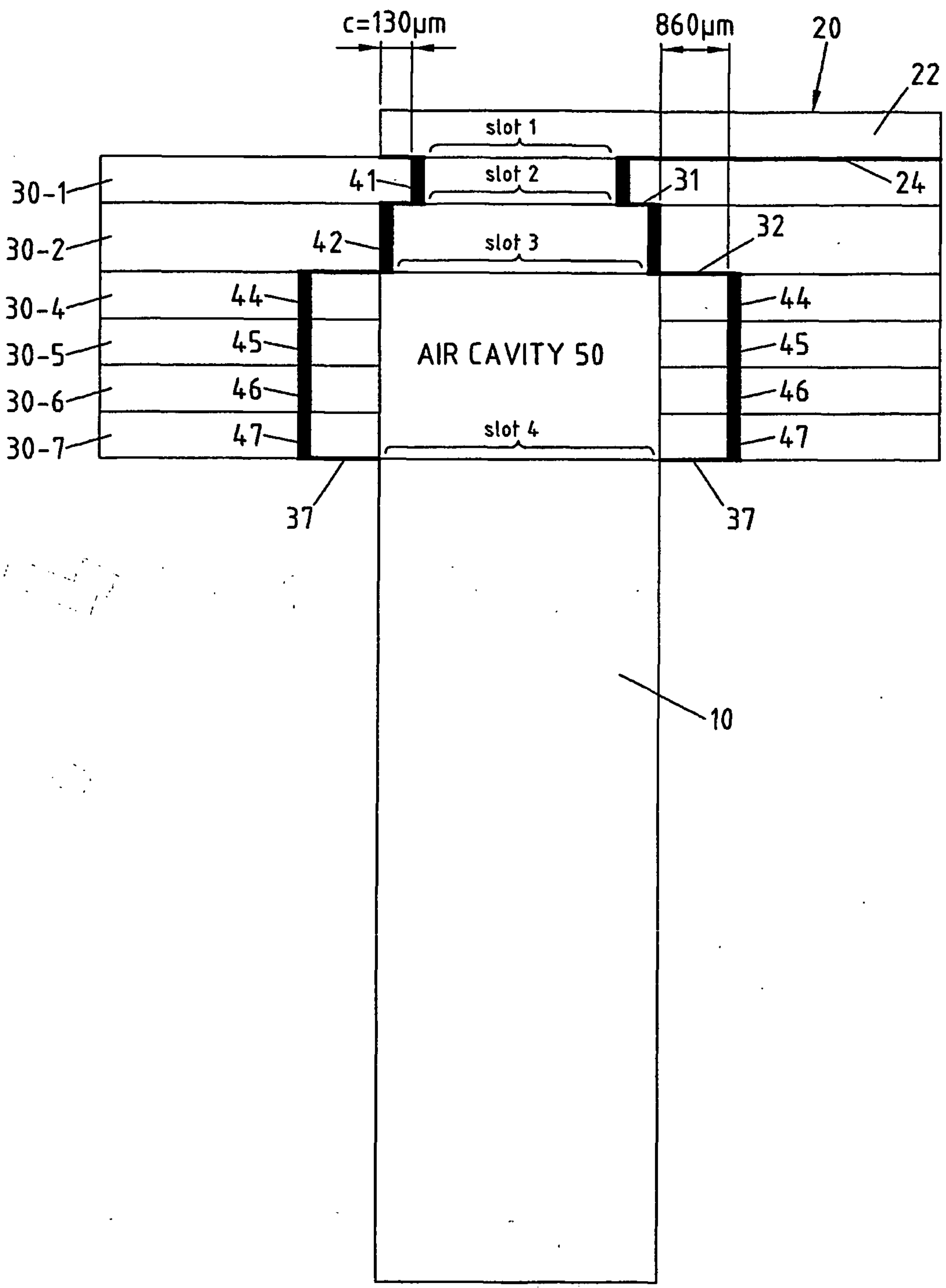
c=130µm
860µm
20
22
slot 1
slot 2
slot 3
slot 4
24
31
32
41
42
30-1
30-2
30-4
30-5
30-6
30-7
44
45
46
47
AIR CAVITY 50
37
10

Fig.7

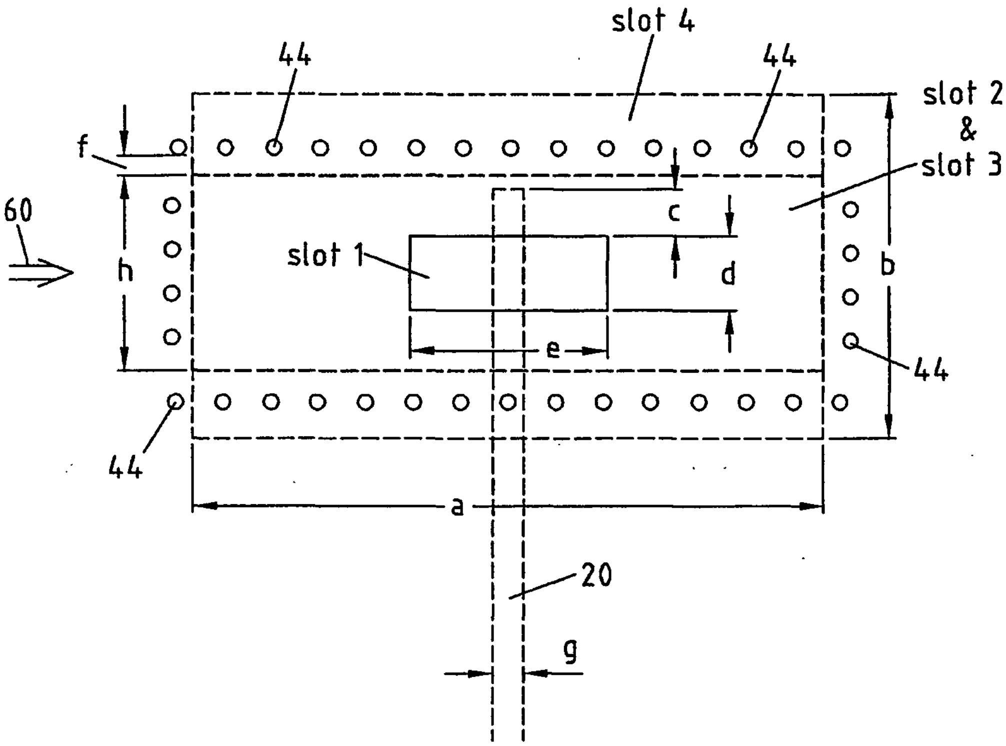

Fig.8

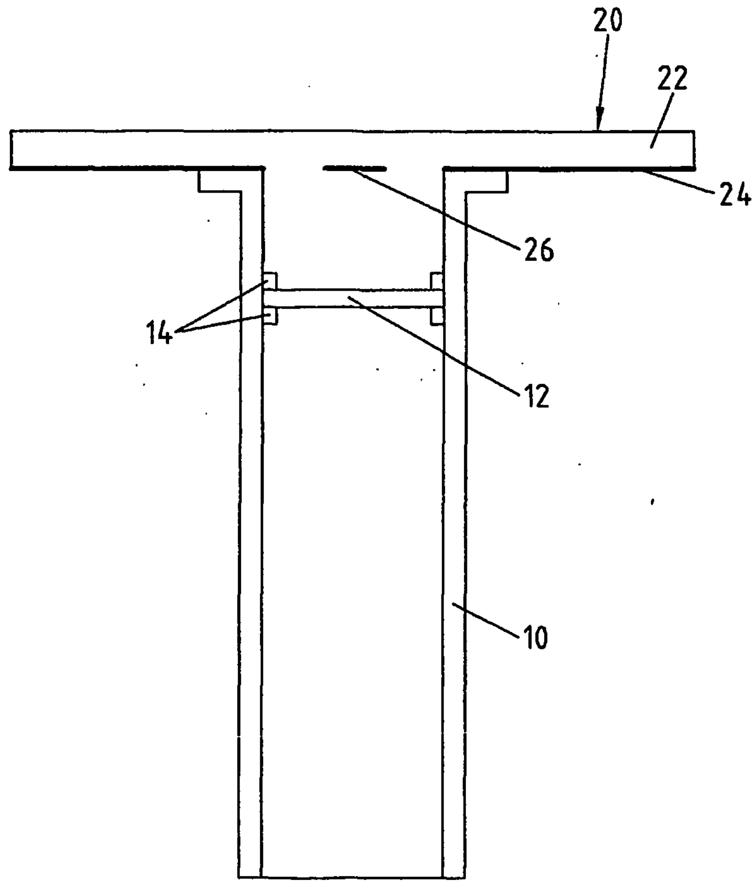

Fig.9 prior art

INTERNATIONAL SEARCH REPORT	Ir al Application No PCT/EP 00/10238

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H01P5/107

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H01P

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

PAJ, EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	HYVOENEN L ET AL: "A COMPACT MMIC-COMPATIBLE MICROSTRIP TO WAVEGUIDE TRANSITION" IEEE MTT-S INTERNATIONAL MICROWAVE SYMPOSIUM DIGEST,US,NEW YORK, IEEE, 17 June 1996 (1996-06-17), pages 875-878, XP000731995 ISBN: 0-7803-3247-4 page 875, right-hand column, line 18 -page 876, right-hand column, line 19; figures 1,2	1,4,19, 22
Y		5,12,16, 20,21
Y	US 5 414 394 A (GAMAND ET AL.) 9 May 1995 (1995-05-09) column 5, line 4 -column 7, line 36; figures 1A-C	5,12

-/--

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
18 April 2001	24/04/2001

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Den Otter, A

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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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